Architectus

2022
4(72)

DOI: 10.37190/arc220406

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Conservation studies of the ruins of the Gothic Kazimierz castle (2nd half of the 14th century) in Koło (Gozdów)

Introduction

The ruins of Gozdów castle (Fig. 1) have been of interest to historians and researchers for many years. Recently, the Koło district[1], as the owner of the object, has started preparations for the development project of the ruins along with the surrounding area, intended in the long term for a communal recreation and cultural centre [1]. In 2019, archaeological research was resumed [2] and architectural [3] and conservation research [4] was ordered[2]. Research on building materials of strongholds in Poland has already been the subject of analyses [5]–[8], but still require continuation.

The purpose of this article is to present the results of the works carried out as part of the revitalization project of the ruins of the castle in Koło. Conservation research conducted at the castle in Koło made it possible to identify building materials: mortars and bricks in terms of their composition, determine their properties as well as assess the state of preservation and identify the causes of damage. Material delamination was analysed *in situ*, the state of preservation was thoroughly assessed by classifying, describing and documenting individual types of damage, samples were taken for testing along with documentation of the sampling sites. Laboratory tests of the collected materials included chemical analysis of mortars, testing of compressive strength, petrographic analysis of bricks and mortars, thermogravimetric analysis, qualitative and quantitative analysis of soluble salts and microbiological analysis of damaged bricks, granulometric analysis of mortar fraction unreacted with HCl, determination of pH, capillary properties of materials, including effective porosity, water absorption by weight, capillary rate. The results of these studies

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[1] The presented article was developed on the basis of [1]. The research was carried out in the period May–October 2021 at the request of the Koło district.

[2] The purpose of conservation research in accordance with the *Ustawa z dnia 23 lipca 2003 r. o ochronie zabytków i opiece nad zabytkami* [Act on the protection and care of monuments of July 23, 2003] [4, art. 3, point 9] is to identify the history and functions of the monument, to determine the materials and technologies used to build it, to determine the state of preservation of this monument and to develop a diagnosis, project and program of conservation works.

Fig. 1. Castle in Koło. A tower and a fragment of the western wall (photo by K. Witkowska, 2020)

Il. 1. Zamek w Kole. Wieża i fragment muru zachodniego (fot. K. Witkowska, 2020)

Fig. 2. Castle in Koło. Fragment of a buttress with a restored boulders faced wall with sandstone blocks (photo by K. Polak, 2020)

Il. 2. Zamek w Kole. Fragment przypory z przemurowanym kamiennym licem z użytymi blokami piaskowca (fot. K. Polak, 2020)

as well as the results of the architectural research, became the basis for developing a program of conservation works.

Historical outline

The castle was the seat of Koło district governor and secured the road leading from Wielkopolska towards Łęczyca through the Warta valley. It was erected on the southern bank of the river, on an artificial hill. The stronghold is mentioned for the first time in 1383 in the chronicle of Janek of Czarnków as the seat of the district governor – Krystyn of Koziegłowy [9, p. 625]. According to Jan Długosz, the construction of the castle was connected with the building action of Kazimierz Wielki, thus listed it among other castles and mansions founded by the ruler before 1370 [10, p. 441]. The condition of the castle deteriorated relatively quickly, because in 1507 the district governor of Koło donated 500 florins for its restoration [11], and at the end of the 16th century the castle was already in ruins. In the interwar period, only basic security works were carried out [12]. In 1953, the ruins of the castle were entered in the register of the monuments. At that time, an inventory was made as well as protection and conservation works were carried out within the curtain walls and the southern corner of the tower. Conservation work was resumed in 1971 and 1987, and the last one was carried out at the beginning of the 21st century [11]. Archaeological works have been conducted in the castle since 2019.

Construction technique of walls

The walls of the castle in Koło were erected using materials traditionally used in the Middle Ages, available locally such as natural stone, brick, lime mortar and river sand. Brick, stone, lime and lime-cement mortars were also used in the repairs.

Rocks – natural stone

Erratic blocks were used to build the stone wall. In the preserved original parts of the wall, large boulders were layered, and smaller pebbles or keels were used to fill voids or level the layer. Wall repairs made later differ in the size of the pebbles, the method of their masonry and the mortar face. They were mostly arranged randomly, and bricks were used to fill the voids between the large boulders. The exception is the rebuilt south-western corner of the base of the tower, where the boulders were arranged in layers, imitating the pattern of the historical stone wall.

Sandstone blocks from Brzeźno[3] [13] (Fig. 2) were also used for the repair of the plinth, probably coming from the ruined parts of the residential tower. This is indicated by the type of material and similar dimensions and method of processing.

In the preserved parts of the residential tower, cuboid squares of irregular dimensions are arranged in layers, forming the facing of opus emplectum. Blocks of stone have a smooth surface or traces of hammering or pointing.

Brick

The walls of the castle were built of properly fired bricks. There are few zendra bricks distinguished by a black-grey colour and slight glazing induced by very high temperature in the kiln. On the cylinder of the tower, they are form a "diaper work". On other elevations they are sporadic and randomly built.

On the basis of petrographic research, for which various bricks from phase II of the castle construction were selected[4], many common features were found as the com-

[3] It is a Miocene (formerly Tertiary) quartzite sandstone. It is characterized by a very high quartz content (over 95%), hardness and high mechanical strength. It has a gray color of varying intensity. From the early Middle Ages, it was used in the architecture and sculpture of Wielkopolska.

[4] Chronological stratification based on architectural research (M. Prarat, U. Schaaf) showed two construction phases: I (3rd quarter of the 14th century) and II (3rd quarter of the 15th century) divided into 9 stages and three successive phases III, IV, V relating to repairs.

Table 1. The results of the study of the capillary properties of historical brick (elaborated by A. Podgórski, M. Chylińska)
Tabela 1. Wyniki badania właściwości kapilarnych historycznej cegły (oprac. A. Podgórski, M. Chylińska)

Dating	Water absorption [m/m %]	Effective porosity [%]	Water capillary rate up to 3 cm [min]
Phase I, 3rd quarter of the 14th century	13.32	24.57	6
	12.96	22.80	7
Phase II, stage 1, 2nd quarter of the 15th century	14.15	25.39	9

position of the grain skeleton is dominated by quartz, next to which feldspar and grains of (crystalline) rocks. The accessory components are oxyhornblende, muscovite flakes, opaque minerals. In both samples, the morphology of the skeleton grains is similar, those with sizes below 0.2 mm predominate, and grains of about 0.8 mm are rare. The matrix is quite heavily sintered, mainly aphanitic with occasionally visible relics of clay minerals. A characteristic feature of the samples is a relatively significant volumetric share of skeleton grains, with a relatively small share of sintered (meta)clay matrix as well as the presence of characteristic, small brownish-black aggregates. These are presumably clasts of the original clay raw material, unhomogenized with the ceramic paste, enriched in Fe-beraing minerals.

Tests of mechanical properties[5] showed negligible differences. Bricks from phase I were characterized by compressive strength in the range of 3.6–4.8 MPa, and from phase II from 3.6 to 4.1 MPa.

Bricks in both historical building phases indicate similar capillary features (Table 1)[6].

Fig. 3. Castle in Koło. An exemplary sample of medieval mortar (elaborated by K. Witkowska, 2020)

Il. 3. Zamek w Kole. Przykładowa próbka średniowiecznej zaprawy (oprac. K. Witkowska, 2020)

Historical mortars

The original mortars assigned to phases I and II of the castle erection exhibit similar petrographic characteristics (Fig. 3). The composition of the grain skeleton of all samples is dominated by quartz, while feldspars and rock grains are rare. Accessory components are represented by amphibole and opaque minerals. The morphology of grains in all samples is similar. The grains are similar in size, do not exceed 1.0–1.2 mm, and exhibit a good and very good roundness. Very fine aggregates, with a diameter below 0.5 mm, dominate (Table 2).

Interesting in the aspect of historical construction techniques are the results of analyses on the mortar binder. On the basis of the petrographic analysis, it was found that carbonate binder (micrite) was present in all examined samples, but it shows some differentiation. Lime lumps (micrite aggregates) isolated from the binder mass were observed in all of them. They are clearly smaller in size, sometimes containing fine grains of quartz with glassy rims. Occasionally, apart from typical lime lumps, the other binder-related, i.e., silicate sinters (overburned lime lumps) formed during the calcination of lime from carbonate raw material containing silicate components (clay minerals or the aforementioned fine-grain quartz) are found (Fig. 4). The occurrence of structures such as silicate sinters in mortars or the presence of fine grains of quartz grains in lime lumps may suggest that the lime was calcined from carbonate raw material containing significant admixtures of silicate components, i.e., quartz, clay minerals or iron minerals. Their presence may indicate latent hydraulic properties of the lime.

The results of thermal analysis[7] also confirm the latent hydraulic properties of the binder. It was found (Table 3) that the content of carbonates in the analysed samples

[5] The tests were performed using the ToniPRAX 1543 hydraulic press from Toni Technik Baustoffprüfsysteme GmbH (measuring range 3–300 kN); control of hydraulic press and processing of results was carried out using the testXpert software.

[6] Water absorption and effective porosity of the samples were determined using the OHAUS PX523m/1 balance, equipped with a density determination kit.

[7] The analysis was performed using a thermal analyzer STA 6000 produced by Perkin Elmer; in the temperature range: 30–1000°C; heating rate of 10 °C/min; N_2 inert gas flow 20 ml/min.

Table 2. Exemplary distribution of the aggregate fraction of the mortar from phase II (elaborated by A. Gralińska-Grubecka)
Tabela 2. Przykładowy rozkład frakcji kruszywa zaprawy z II fazy (oprac. A. Gralińska-Grubecka)

	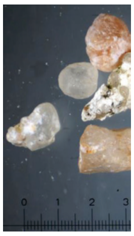	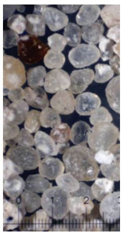			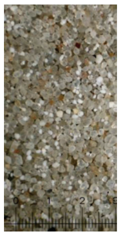	
Filler fraction [mm]						
above 1.6	1.6–1.0	1.0–0.5	0.5–0.315	0.315–0.2	0.02–0.071	below 0.071

Fig. 4. Castle in Koło. Close-up of the mortar in the joint with visible fragments of calcined limestone (photo by K. Polak, 2020)

Il. 4. Zamek w Kole. Zbliżenie zaprawy w spoinie z widocznymi okruchami kalcynowanego kamienia wapiennego (fot. K. Polak, 2020)

ranged from 10 to 34 wt.%. Therefore, it is relatively low, which indicates the abundance of silicate filler in the binder. In addition, the samples are characterized by low values of CO_2/H_2O ratios, which is characteristic of mortars with a lime binder, showing hydraulic properties [14]. However, it should be noted that in several of the analysed samples, in the range in which the hydrated hydraulic components undergo thermal dissociation, other physical or chemical changes occur simultaneously, which results in overlapping weight-loss effects. The obtained values may be influenced, for example, by the presence of clay minerals or FeOOH. Therefore, some values may be accompanied by a greater measurement error.

Based on the chemical analysis, commonly used to determine the proportions of the reacted and unreacted with hydrochloric acid components of the lime mortars, it was found that the proportions of the carbonate binder and silicate filler fall within a fairly wide range, mostly between 1:1.4 and 1:2.5. For several mortars, proportions >1:3 were determined. Chemical and macroscopic analysis confirm the hydraulic nature of the mortars (Fig. 5). A large difference in the proportions within the analysed samples assigned to individual construction phases does not have to result from intentional action. It may indicate carelessness of contractors or imperfect production technology. This conclusion is confirmed by in situ observations. In many places, lumps and crumbs of binder of various sizes and shapes are visible on the fractures of the mortar. They occur irregularly, occasionally in clusters.

Another reason for the large discrepancy in filler-binder proportion may results from the heterogeneity of the lime rock used to make the calcine binder. Small outcrops of carbonate rocks of Cretaceous age occur in the vicinity of Koło. They are dominated by marls, marly limestones, and less common limestones, which could have been used as a raw material. These rocks, apart from calcium carbonate, contain magnesium carbonates and clay minerals, detrital grains, in various proportions. As a raw material, calcareous gyttja could also be used. It is a common sediment in ribbon lakes (for example the Lake Gopło), containing, apart from organic matter and calcium carbonate, also minor clastic components and clay minerals.

The proportions of mortar components determined in laboratory tests, due to the presence of hydraulic compounds, do not reflect the proportions of mortar components understood as the ratio of binder to aggregate, which is usually the basis for developing mortar recipes for renovation works. For the proper selection of mortars for the planned works, it is equally important to determine the capillary properties and mechanical strength of the materials.

The determined effective porosity of historical mortars (Table 4) ranges from 22.9 to 34.8%, usually around 30%. Water absorption by weight is relatively high – it ranges from 12.9 to 22.9%. It should be emphasized that the mortars from phase I show both the highest porosity (34.8%) and water absorption (22.9%). Large differences in the rate of capillary rise can be explained by the heterogeneity of the mortars used for the tests, because the largest possible to obtain fragments, heterogeneous in nature, were tested.

A large dispersion of results was obtained in the study of the mechanical properties of mortars (Table 5). The possibility of obtaining only small-volume samples with the above-mentioned heterogeneity of mortars and the standard requirements of the testing equipment used, limited the number of tests performed. The determined compressive strength of mortars is very high, ranging from slightly more than 3.7 to 12.0 MPa. The average value is about 7 MPa.

Table 3. Results of thermogravimetric analyses (elaborated by M. Chylińska)
Tabela 3. Wyniki badań termograwimetrycznych (oprac. M. Chylińska)

	Weight loss in the temperature range [%]			Component content [wt.%]		
Sample/ Dating	30–120	200–600	600–1000	Calcium carbonate	Other (thermally inactive) components	CO_2/H_2O
16/Phase I	0.084	1.312	7.244	16.47	83.44	5.53
19/Phase I	0.120	a	11.406	25.94	73.94	a
36/Phase I	0.563	2.857	4.358	9.91	89.53	1.53
38/Phase I	0.629	1.997	12.517	28.47	70.91	6.27
2/Phase II, step 1	0.181	a	14.763	33.57	66.24	a
5/Phase II, step 1	0.525	2.101	7.633	17.36	82.12	3.63
10/Phase II, step 6W	0.138	a	7.962	18.11	77.02	a
12/Phase II, step 7W	0.094	a	8.096	18.41	81.50	a
P3/Phase II, step 1	0.053	a	6.749	15.35	84.60	a
P10/Phase II, step 2	0.252	a	11.667	26.53	69.27	a
P12/Phase II, step 8W	0.114	a	8.343	18.97	75.13	a
P15/Phase II, step 9W	0.115	a	7.857	17.87	78.08	a
34/Phase II, step 1	0.525	1.785	9.959	22.65	76.83	5.58
35/Phase II, step 1	0.317	1.762	5.858	13.32	86.36	3.33
41/ Phase II, step 1	0.043	0.804	5.914	13.45	86.51	7.36
8/Phase III	0.028	0.959	6.190	14.08	85.90	6.46
39/Phase IV	0.269	1.356	6.083	13.83	85.90	4.49
40/Phase V	0.178	1.743	10.333	23.50	76.32	5.93

a – overlapping weight-loss effects make it difficult to determine the amount of water in hydraulic components.

Fig. 5. Exemplary sample documentation: 1 – sample, 2 – break mortar, 3 – aggregate and residues after HCl reaction, 4 – magnification of an underburned lump of calcined limestone (photo and elaborated by K. Witkowska, 2020)

Il. 5. Przykładowa dokumentacja próbki: 1 – próbka, 2 – przełam zaprawy, 3 – kruszywo i części nierozpuszczalne w HCl, 4 – zbliżenie grudki kalcynowanego kamienia wapiennego (fot., oprac. K. Witkowska, 2020)

Table 4. Test results of capillary properties of exemplary historical mortars (elaborated by A. Podgórski, M. Chylińska)
Tabela 4. Wyniki badania cech kapilarnych przykładowych zapraw historycznych (oprac. A. Podgórski, M. Chylińska)

Dating	Water absorption [m/m %]	Effective porosity [%]	Water capillary rate up to 3 cm [min]
Phase I, 3rd quarter of the 14th century	22.85	34.80	34
	15.88	29.62	60
Phase II, stage 1, 2nd quarter of the 15th century	15.25	26.91	3
	12.93	22.93	23
	16.73	28.62	15
	14.58	25.12	26
	20.92	33.14	20
	17.79	29.05	106

Table 5. Results of the compressive strength test of historical mortars (elaborated by A. Podgórski)
Tabela 5. Wyniki badania wytrzymałości mechanicznej zapraw historycznych (oprac. A. Podgórski)

Dating	Compressive strength		
	Value range [MPa]	Average value [MPa]	Coefficient of variation [%]
Phase I, 3rd quarter of the 14th century	3.7–6.4	5.4	19
Phase II, stage 1, 2nd quarter of the 15th century	5.1–12.0	8.8	27

Modern mortars

Modern mortars were used as masonry mortars in parts made in the 20th century and as mortars to fill mortar losses in the joints of a brick wall (occasionally) and a stone wall (in many places). Based on macroscopic observation, several types differing in structure, cohesiveness, colour and type of filler were identified.

Most of the examined mortars are characterized by cement and cement-lime binders. The capillary properties of the mortars (Table 6) are various, however, sufficient from the conservation point of view. These mortars transport water faster, due to their high porosity and aggregate content.

Renders

The renders cover the arches of the window openings in the top storey of the tower. Based on observations, it can be concluded that they are not the same on all surfaces. Presumably, both original and secondary renders have been preserved on the arches. The mortar samples have not been studied due to lack of access.

In addition to the described primary building materials, in very small areas of the face of the wall, a fragmentary red painting layer was observed, which in the past could have been a layer unifying the façade. It is very well bonded to the substrate and does not form a clearly separated coating.

Preservation state

The preserved walls of the castle in Koło are everlasting ruin and will be maintained in this form for the future. The analysis of the state of preservation was aimed at identifying changes and damages that may pose a threat to the materials and currently or in the long term may threaten the durability of both individual materials and the structure of the wall, i.e., the entire building.

Table 6. Test results of capillary properties of modern mortars (elaborated by A. Podgórski, M. Chylińska)
Table 6. Wyniki badania cech kapilarnych zapraw współczesnych (oprac. A. Podgórski, M. Chylińska)

Dating	Water absorption [m/m %]	Effective porosity [%]	Water capillary rate up to 3 cm [min]
Phase III, 1st half of 20th century	18.83	30.91	8
Phase IV, 2nd half of 20th century	13.28	24.67	32
Phase V, early of 20th century	15.05	27.21	5

Fig. 6. Castle in Koło. The inner side of the western wall with numerous graffiti and complemented bricks on the wall face. The softly ending crown of the breast wall is noteworthy (photo by K. Witkowska, 2020)

Il. 6. Zamek w Kole. Wewnętrzna strona muru zachodniego z licznymi graffiti, uzupełnieniami lica. Uwagę zwraca miękko zakończona korona przedpiersia (fot. K. Witkowska, 2020)

Brick wall

Due to the raised level of the courtyard, the stone pedestal of the western wall and the northern part is covered with soil in along its entire length. A similar situation occurs within the relics of the southern wall. Direct contact of the brick wall with the soil is often the reason of high moisture content, but during the tests (May–October) no clearly increased level of moisture in the structure of the walls in the ground floor was found. In several places, damage caused by salt crystallization was noted. Tests confirmed the amount exceeding the permissible standards (about 4%; 6.2%) [15][8].

Historical brick wall – from the first two building phases

The original face is preserved on most of the surface of the wall. However, on large stretches, the face layers of the wall became loosened, presumably as a result of the cracking of the perpends. In many places, the face has been reconstructed, but large losses are still present on the southern wall, parts of the northern one and in many smaller places. The facings on the buttresses are in poor condition.

Colonies of microorganisms present in various amounts on most surfaces do not provide a direct danger to the facility. Indirectly participating in the circulation of matter, they contribute to the formation of organic deposits that favour the colonization of walls by higher organisms – herbaceous and woody plants. Their growth on the walls is dangerous, primarily due to the mechanical action of the roots.

Graffiti as well as numerous signatures and initials engraved in bricks, especially numerous on the walls from the side of the courtyard, should be mentioned as another damage that did not significantly affect the state of preservation, but negatively changed the appearance of the wall (Fig. 6). The painted inscriptions disturb the perception of the monument and, despite a certain cultural value, should be treated as an act of vandalism and removed.

A major conservation and restoration problem is the state of preservation of the bricks (Fig. 7). Most of their face has not been preserved. Its destruction is most often the result of washing out or shedding of the surface layer. In many places, the cavities form depressions and niches, sometimes covering the entire volume of the brick. They are visible from a distance as soft-edged cavities. It has been assumed in the literature that this type of damage is associated with the presence of nitrifying bacteria, which, as a result of metabolism, produce acids capable of decomposing rock-forming minerals (aluminosilicates in this case). Damage initiated by bacteria is magnified and intensified by the action of other factors, e.g., wind. The conducted microbiological tests did not confirm the excessive content of nitrifying bacteria on the surface of the damaged bricks[9], but their slow and long-term effect is possible.

Shreds, forging and similar places are in destruct condition. These areas are dominated by damaged, irregularly cracked and crumbled bricks bonded with mortar that is crumbled, uneven, with many depressions, voids, etc. (Fig. 8).

[8] The degree of salinity of the samples was determined by the conductometric method using the CPC-411 device by Elmetron. The qualitative and quantitative composition of the aqueous sample extracts was determined using the EA102 capillary electrophoresis apparatus (Villa Labeco, Slovakia).

[9] Microbiological tests were performed at the Department of Environmental Microbiology and Biotechnology of the Nicolaus Copernicus University in Toruń by Maria Swiontek-Brzezinska, PhD, DSc.

Fig. 7. Castle in Koło. Examples of the state of preservation of the medieval face of the wall (photo by K. Polak, 2020)

Il. 7. Zamek w Kole. Przykłady stanu zachowania średniowiecznego lica muru (fot. K. Polak, 2020)

Fig. 8. Castle in Koło. Examples of the state of preservation of the tower walls (photo by K. Polak, 2020)

Il. 8. Zamek w Kole. Przykłady stanu zachowania murów wieży (fot. K. Polak, 2020)

The face of the historical bricks is covered with unevenly dark, thin layers well bonded to the ceramics. Besides to the unfavourable aesthetical appearance, they do not have a destructive effect on the brick.

Historical mortars are mostly in good condition, hard and cohesive. In many places they are preserved with the paths of masonry tools on the surface. The damage that occurred – slight washing out at the edges, legibility of gaps, cracks, small losses should be classified as caused by natural erosion of the mortar.

Some of the mortars in the joints between the historical bricks were complemented with mortars during modern or contemporary repairs. The state of preservation of these mortars is varied and depends primarily on their composition, i.e., the type of binder and its proportions with the filler. In many places, modern mortars have disintegrated and washed out on the surface and are in much worse condition than the historical ones.

Brick wall – modern repairs

In some areas, especially in the basement, the layers of bricks near the surface are saturated with salts or covered with their crusty layers, and the mortars are disintegrated and scattered. It was found that in many places the bricks were laid with mortar with a large amount of cement, and only the top layer of joints was made of lime/cement-lime mortar, which was destroyed.

Fig. 9. Castle in Koło. The crown of the breastwork softly prepared during renovation works in the 20th century (photo by K. Witkowska, 2020)

Il. 9. Zamek w Kole. Korona przedpiersia miękko opracowana podczas prac remontowych w XX w. (fot. K. Witkowska, 2020)

Pavements and covers

During the last renovations, the planes of the crown of the walls were protected with a covering of bricks laid on the damaged crown without levelling the layers, which resulted in its plastic shape (Fig. 9). While the contemporary roofing on the crowns is mostly completely preserved, the pavements have missing bricks in many places, especially on the edges, where the inside of the wall structure is exposed. Apart from natural factors, the destruction of the covers is facilitated by walking on the pavements and the tops of the walls. The places of climbing are also on the tromps on the tower. Their bevels were covered with a layer of mortar to protect the surface from water and stabilize the damaged bricks. Currently, due to cracks and mortar losses, the covers do not have a protective function. The formation of cracks, hollows and voids is conducive to the colonization of these places by vegetation, which is a reason for large numbers of various plant species growing on pavements, caps and slanted and horizontal places with an exposed structure.

Noteworthy are mineral layers on the face of the wall below the planes. They were formed as a result of deposition of mortar components on bricks washed away by rainwater.

Historical face of the stone wall

The original face of the stone wall is preserved in only a few fragments. The mortar in the joints usually comes from later repairs, but the boulders are firmly embedded and the layer system is clarified. The preserved original mortars are cohesive and compact, but cracks appeared in many places, and gaps of various widths appeared directly at the boulders.

The face of the stone wall – repairs

Most of the face of the stone wall (Fig. 10) was classified as repairs and additions. They are locally covered with microbial layers and graffiti. The mortars in the joints are preserved in various condition, due to various composition of the mortar and their technique of preparing. The mortar is washed out in many places. Some of the restorations do not meet the basic restoration requirements due to the accidental selection of the material, careless, unprofessional surface treatment and incorrect parameters of the applied mortar.

Sandstone squares set between granite boulders require special attention. The condition of these elements is poor. The stone has disintegrated, locally delaminating. The edges of the blocks are weakened and crumbling. The surface is covered with unevenly dark layers. The disturbing state of preservation of the sandstone squares results primarily from the intensive action of the destructive factors on the porous rock surrounded by materials with different capillary properties: igneous rocks, which are the main building material of the wall and mortars.

Summary

Conservation research is an essential element of conservation design, especially in this type of architecture with its transformations and various conditions [16]. Conservation studies of the ruins of the castle in Koło made it possible to recognize its construction technique, repairs and state of preservation, and to assess them from the conservation and restoration point of view. The findings from the conservation and architectural research became the basis for formulating conservation conclusions regarding both the form of the object and the technological details of the planned

Fig. 10. Castle in Koło. A fragment of the outer façade of the west wall – visible extensive restorations of brick and stone faces as well as microbiological layers (photo by A. Gralińska-Grubecka, 2020)

Il. 10. Zamek w Kole. Fragment elewacji zewnętrznej muru zachodniego – widoczne rozległe uzupełnienia lica ceglanego i kamiennego oraz nawarstwienia mikrobiologiczne (fot. A. Gralińska-Grubecka, 2020)

works. It was stated that the walls of the castle should remain in a state of ruin with full access to them and leaving modern conservation interventions as an element of the building history of the monument. Conservation intervention should be limited to a minimum, mainly where it is required by the state of preservation, the presence of harmful materials and the need to protect the structure of the walls. Such places are, among others, pavements, crowns of walls and planes. Areas that are difficult to implement and require prudence from the contractor are all shreds and forging. These places should remain in the form of a "destroyed wall", while stabilizing cracks in bricks and mortars and filling in losses only in those places that may contribute to further destruction of the wall.

After examining the contemporary mortars used in the 20th century, most of them were allowed to remain in the building[10]. It was found that despite the content of cement binders, physical and mechanical parameters do not provide a risk to historical materials.

Very good, despite the passage of years, state of preservation of historical mortars, high mechanical strength confirmed during in situ and laboratory tests, excellent adhesion, very good capillary properties and the hydraulic nature of the binder prompt further research into the technology of the medieval masonry mortars. The analysis of the castle in Koło from two perspectives – architectural and construction design as well as conservation research gives the opportunity to comprehensively address the problem of the preservation of the facility and develop a valuable, comprehensive project based on the interdisciplinary knowledge and experience of the specjalists in various fields.

Translated by
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[10] Recommendations included in the architectural research documentation (M. Prarat and U. Schaaf).

Acknowledgements
The research was carried out as a part of the revitalization project of the ruins of the castle in Koło at the request of the Koło district (Agreement no. IP.272222020).

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Abstract

Conservation studies of the ruins of the Gothic Kazimierz castle (2nd half of the 14th century) in Koło (Gozdów)

The purpose of this article is to present the conservation research carried out as part of the revitalization project of the ruins of the castle in Koło. Basis of the recognition of the monument's construction technique, identification and determination of the properties of historical and contemporary materials, assessment of the state of preservation and analysis of destructive factors developed a program of conservation works. Research was carried out considering the findings of architectural research. Laboratory tests of the collected material were carried out by a wide team of employees using specialized research techniques. Their results are presented in this article and include petrographic, chemical and thermogravimetric analyses of mortars, rocks and bricks, their capillary and mechanical properties, salinity analysis and microbiological analyses of materials. The undeniable value of the conducted research is a detailed diagnosis of historical building materials, which is a significant contribution to the knowledge of old construction techniques.

Key words: medieval architecture, building materials, material testing, architectural conservation

Streszczenie

Badania konserwatorskie ruin gotyckiego zamku kazimierzowskiego (2. poł. XIV w.) w Kole (Gozdów)

W artykule przedstawiono wyniki badań konserwatorskich zrealizowanych w ramach projektu rewitalizacji ruin zamku w Kole. Obejmowały one rozpoznanie techniki wykonania zabytku, identyfikację i określenie właściwości materiałów historycznych i współczesnych, ocenę stanu zachowania, analizę czynników niszczących, które wraz z wynikami badań architektonicznych stanowiły podstawę opracowania programu prac konserwatorskich obiektu. Analizę zgromadzonego materiału realizował szeroki zespół z wykorzystaniem specjalistycznych technik badawczych. Wyniki przedstawione w artykule obejmują petrografię, analizę chemiczną, termograwimetrię oraz właściwości kapilarne i mechaniczne zapraw, skał i cegieł, stopień zasolenia oraz analizy mikrobiologiczne materiałów. Niepodważalną wartością przeprowadzonych badań, stanowiącą znaczący wkład w zasób wiedzy, jest szczegółowe rozpoznanie historycznych materiałów oraz zastosowanych technik budowlanych.

Słowa kluczowe: architektura średniowieczna, materiały budowlane, badania materiałów, konserwacja architektury